University of Pretoria

Effects of climatic conditions and agro-ecological settings on the productive efficiencies of small-holder farmers in Ethiopia

Temesgen Tadesse Deressa

Working paper 223

June 2011

Effects of climatic conditions and agro-ecological settings on the productive efficiencies of small-holder farmers in Ethiopia

Temesgen Tadesse Deressa*

June 21, 2011

Abstract

This study argues that the adaptation measures farmers take to reduce the negative impacts of climate change do affect farmers' efficiency of production. To support this argument, two steps were followed to understand how climatic factors especially long term average seasonal rainfall and temperature; and agro-ecological settings affect production efficiency in Ethiopian agriculture. In the first step, the stochastic frontier approach was employed to analyze the farm level technical efficiency. In the second step, the tobit regression model was adopted to analyze how climatic and agro-ecological settings affect efficiency scores derived from the first step. Results from the first step indicated that the surveyed farmers have an average technical efficiency of 0.50; with significant output elasticits of labor, draft power and tractor. Results from the tobit regression model showed that soil types, run-off, seasonal climatic conditions and agro-ecological settings affect technical efficiency in Ethiopian agriculture.

JEL codes C53 Q25 Q54

Key words Technical efficiency, seasonal climate, agro-ecology, Ethiopia

1 Introduction

In contrary to the "poor but efficient hypothesis" of Stiglitz (1964), studies in developing nations in general (Mkhabela et al, 2010; Abu Orefi and Kirsten, 2009; Bedasa, 1997) and in Ethiopia (Belete et al 1993; Admassie and Heidhues 1996; Hailu et al, 1998) in particular indicate that there is a high level of inefficiency in small holder agricultural production. Studies also show that in addition to the differences in the use of purchased inputs, differences in the physical environments of farms do affect farm level technical efficiency (Ben Henderson and Ross Kingwell, 2005).

Farrell (1957; cited in Ben Henderson and Ross Kingwell, 2005) indicated that environmental factors such as air and water quality, climate and location should be considered in efficiency analysis as they affect efficiency. To this effect, some studies have considered to analyze the impacts of environmental factors on the efficiency of farmers (Ben Henderson and Ross Kingwell, 2005; Donald and Frank, 2002; Piesse et al 1996). For instance, Ben Henderson and Ross Kingwell (2005) considered rainfall as input to production of wool in Australia along with other purchased inputs such as labor and materials in efficiency analysis. Donald and Frank (2002) revealed the relationship between environmental factors such as temperature and rainfall and efficiency scores. Additionally, Piesse et al (1996) observed the correlations between efficiency scores and rainfall patterns in South Africa to describe the effect of rainfall on efficiency.

Concerns over the effects of environmental factors mainly climatic factors on agricultural production are growing due to global climate change (IPCC, 2001). Studies indicate that changes in the

*Centre for Environmental Economics and Policy in Africa (CEEPA), Department of Agricultural Economics & Rural Development, University of Pretoria, RSA, Room 2-13, Agric. Annexe, Pretoria 0002, South Africa. E-mail: ttderessa@yahoo.com

patterns of rainfall and temperature over the past years have negatively affected agriculture in Sub-Saharan Africa (Kurukulasuriya and Mendelsohn 2008; Hassan and Nhemachena 2008). Research results further showed that Sub-Saharan Africa needs to adapt more to reduce the negative impacts of future changes in climate (Hassan and Nhemachena 2008). More over, studies have also identified different farm level adaptation practices that farmers undertake to reduce the negative impacts of climate change (Deressa et al 2009; Kurukulasuriya and Mendelsohn 2008).

Adaptation to climate change refers to adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (IPCC, 2001). Farm level adaptation depends on technology; soil types, the capacity of farmers to detect climate change and undertake necessary actions (Maddison, 2006; Kurukulasuriya and Mendelsohn, 2008; Hassan and Nhemachena, 2008). Farm level adaptation practices consist of diversification, use of different technologies (e.g. availabilities of different varieties of crops and livestock species and irrigation), planting trees, soil conservation, changing planting dates, and a host of agronomic practices that involve costs, causing economic damages that are reflected in revenues (Mendelson et al, 1994). Studies further show that diversification and technology choices affect production efficiency (Donald and Frank, 2002) clearly indicating that adaptation does affect production efficiency. A study by Alem et al (2010) revealed that rainfall patterns affect fertilizer use decisions by farmers in Ethiopia. The Alem et al (2010) study implies that climatic factors do affect production efficiency as these factors influence the amounts of inputs used in production. Moreover, studies indicate that farmers in Ethiopia have adapted to climate change (Deressa et al. 2009; Deressa and Hassan, 2009). Therefore, in this study; it is argued that these adaptive behaviors in responses to climatic factors do affect productive efficiency in Ethiopia.

Studies have been undertaken to analyze the production efficiency of Ethiopian farmers (Belete et al 1993; Admassie and Heidhues 1996; Hailu et al, 1998). Studies have also been undertaken to measure the impact, adaptation options and vulnerability of Ethiopian agriculture to climate change (Deressa 2010). The studies on efficiency assessment in Ethiopia focused only on measuring efficiency of production and have not addressed how climatic factors affect production efficiency and how efficiency varies across the vast agro-ecological settings of the country. Results from climate change studies are limited to assessing adaptation, impacts and vulnerability without addressing how climatic factors affect production decisions, and hence efficiency. The knowledge of how climatic factors affect production efficiency and how efficiency varies across different agro ecologies can assist policy in choosing agricultural technologies that are more adaptable to specific agro- ecologies and enhance sustainable development of the agricultural sector in the face of climate change.

Therefore, the main objective of this study is to analyze how climatic factors especially seasonal rainfall and temperature affect production efficiency in Ethiopian agriculture. Moreover, the study compares production efficiencies across the different agro- ecological zones of Ethiopia. This paper is organized as follows. Section two describes study area and data sources. Section three presents the empirical model. Section four discusses the results and section five concludes and gives policy recommendations.

2 The study area and data

Ethiopia has diverse agro-ecologies, which enable the production of a variety of crops and livestock. The agro-ecological zones in Ethiopia are defined on the basis of temperature and moisture regimes (MoA 1998). According to the Ministry of Agriculture (1998), Ethiopia has 18 main agro-ecological zones. Of the 18 zones, 11 zones representing more than 74% of the country were selected. These 11 zones along with the agro-ecologies are presented in Table 1. The selected zones represent a part of Africa-wide study on the economic impact of climate change on agriculture coordinated by the Centre for Environmental Economics and Policy in Africa (CEEPA), University of Pretoria and Yale University. The data collected for this climate impact study which consists of household, climatic, runoff and soil data is used for this study.

The household data comprised of a sample of 1000 farmers randomly selected from different agro-ecological settings of the country, who were believed to be representatives of the whole nation. A total of 50 districts (20 farmers from every district) were purposely selected, starting from the extreme highlands of the southeastern regions of the Oromia Regional State to the lowlands of the Afar Regional States in Ethiopia. The interviews with the farmers took place during the 2003/2004 production seasons, which included asking different attributes of farmers.

Long-term average climate (normal) for the survey districts were collected from two sources. Long- term average temperature data for the years 1988-2003 was obtained from the US Department of Defense (Basist et al., 2001). The long-term average precipitation data for the years 1977-2000 was obtained from the African Rainfall and Temperature Evaluation System (ARTES) (World Bank 2003). The soil data was collected from the Food and Agricultural Organization (FAO, 2003). The hydrological data (flow and runoff) was obtained from the University of Colorado (IWMI/ University of Colorado 2003).

2.1 Econometric model

This study adopted two methods to analyze farm level technical efficiency and the factors that affect farm level technical efficiency. These are the stochastic production frontier model, which was employed to analyze the farm level production efficiency and the tobit model which was adopted to analyze the factors that affect technical efficiency.

The stochastic production frontier model was introduced by Aigner, et al. (1977), and Meeusen and van den Broeck (1977). In the stochastic production frontier model, the disturbance term (ε) is composed of two parts; one to accounts for random effects and the other to represents technical inefficiency. Assuming the log-linear Cobb-Douglas form, the model can be specified as:

$$\ln Y_j = \ln \beta_0 + \sum_i \beta_i \ln X_{ij} + \varepsilon_j \tag{1}$$

Where, the Output variable**:** Y_j = Value of crops produced per farm in Ethiopian Birr, Input variables: X_{1j} = Seed used in kg; X_{2j} = human labor used in man-days; X_{3j} = machine power used in tractor hours; X_{4j} = animal power used in oxen hours; X_{5j} = Farm size in hectares; X_{6j} = fertilizer used in kg; 1n = natural logarithm and ε_i which is defined as:

$$\varepsilon_j = V_j - U_j \tag{2}$$

j = 1, 2 .... n farms.

Where V_j = part of error term that accounts for random effects and; U_j = part of the error term that accounts for inefficiency.

V_j is assumed to be independently and identically distributed as N (0, σ^2v), independent of U_j. U_j is assumed to have a non-negative (one-sided) half-normal distribution with I |N (0, σ^2u)| (Neff et al. 1993) and Dawson and Lingard (1989).

Defining σ^2v and σ^2u as the variances of the random effects (v) and the sources of the inefficiency (u) implies that:

$$\sigma^2 = \sigma^2 v + \sigma^2 u \tag{3}$$

The total variation of output from the frontier which can be attributed to technical efficiency can be calculated from the ratio of the two standard errors (Jondrow et al. 1982; Battese and Corra, 1977) as:

$$\lambda = \frac{\sigma_u}{\sigma_v} \tag{4}$$

or

$$\gamma = \frac{\sigma_u^2}{\sigma_v^2} \tag{5}$$

The technical efficiency (TE_j) of the jth farmer was estimated as the expected value of the exponential of technical inefficiencies conditional on the error term ε_j given as:

$$TE_j = E[\exp(-U_j)|(V_j - U_j)] \tag{6}$$

As U_j is a non-negative random variable, the technical efficiency estimates lie between zero and one; in which the value of one indicates that the farm is technically efficient.

The tobit linear regression model was adopted to analyze the impacts of climatic conditions and agro- ecology on the farm- level technical efficiency estimates obtained from equation (**??**). The tobit model was selected as the technical efficiency scores, representing the dependent variable, are censored with values ranging between 0 and 1 (Llewenlyn and Williams 1996). The independent or explanatory variables for the tobit model which consist of different environmental and socio economic variables are described in Table 2.

3 Results and discussions

The ordinary least square (OLS) estimates of the Cobb-Douglas production function revealed that labor, tractor and animal power have significant impact on the output (Table 3).

Results from the stochastic frontier analysis indicate that σ_u^2 is significantly different from zero (X^2= 27.16 with probability value less than 0.001) justifying the use of stochastic frontier analysis. Results further show that the output elasticits of labor, draft power and tractor significantly enhance efficiency levels. These imply that availability of more draft power and mechanization especially the use of tractors do increase efficiency of production (Table 4).

The efficiency scores of the survey farmers (estimates obtained from equation (6)) ranged from 4.2 to 87 percent with a mean of 0.50. This implies that, in the short run, there is a scope for increasing production by 50% by adopting the technology and the techniques used by the best practice farmers. In addition to calculating the overall average technical efficiency score of the survey farmers, the average technical efficiency of farmers living under each agro- ecological settings were calculated. Results indicated that the mean technical efficiencies vary between 41 and 61 percent in the different agro-ecologies. For instance, the technical efficiency score of farmers living in Hot to warm sub-moist lowlands which is reported as 0.53 is obtained by calculating the mean of the technical efficiencies of the households living in this specific agro-ecology and the analysis of the other agro-ecologies also follow the same procedure. Table 5 gives the means technical efficiencies across the different agro-ecological settings studied.

As expected, results from the tobit regression model shows that soil types, run-off, seasonal climatic conditions and agro-ecological settings affect technical efficiency (Table 6). For instance, increasing spring and summer temperatures reduce technical efficiency. This could be due to the fact that farmers are forced to voluntarily give up the most efficient mix of inputs and choose to produce at lesser efficiency level to adapt to higher temperature during these two critical crop growing seasons. On the other hand, increasing fall temperature increases efficiency. This could be due to the fact that increasing temperature during the fall season is beneficial for harvesting (Deressa and Hassan, 2009).

Increasing precipitation during the winter season reduces efficiency. This could be due to the fact that winter is a dry season, so increasing precipitation slightly with the already dry season may encourage diseases and pests .Increasing summer and spring precipitation increases efficiency. Summer and spring are critical crop growing seasons and increasing precipitation during this seasons relax the water constrains and enhances production efficiency. Fall precipitation reduces efficiency which could be due to crops' reduced water requirement during the harvesting season (Deressa and Hassan 2009). Results further show that technical efficiency scores significantly vary across the different agro-ecological settings of Ethiopia (Table 6)

For instance, farmers living in Hot to warm sub-moist lowlands, Tepid to cool sub-moist mid-highlands, Tepid to cool moist mid-highlands, Cold to very cold moist Afro-alpine, and Hot to warm humid lowlands are significantly more efficient than farmers living in Tepid to cool sub-moist mid-highlands. Farmers living in Hot to warm per humid lowlands are significantly less efficient than farmers living in Tepid to cool sub-moist mid-highlands. These imply that agro-ecology based technologies which can easily be adaptable to climate change and increase production efficiency should be of priority for policy makers to increase productivity and adaptability to climate change.

4 Conclusion

Based on the fact that production efficiency is equally affected by uncontrolled environmental factors as controlled factors of production such as fertilizer and input use, this study investigated the effect of both environmental and controllable inputs on the production efficiency of farmers in Ethiopia. To this effect, the study relied on primary and secondary data obtained from different sources. The stochastic frontier method is employed to analyze the technical efficiency of farmers. The tobit regression model is used to analyze the effects of seasonal climatic factors and agro-ecological settings on technical efficiency.

Results from the stochastic frontier model show that the output elasticits of labor, draft power and tractor significantly enhance efficiency levels. These imply that availability of labor especially during peak seasons, more draft power and mechanization especially the use of tractors do increase efficiency of production. Although not significant, the elasticites of fertilizer, farm size and seed are do also positively influence efficiency. More over, results from the tobit regression model shows that soil types, run-off, seasonal climatic conditions and agro-ecological settings affect technical efficiency. These imply that agro-ecology based technologies which can easily be adaptable to climate change and increase production efficiency should be of priority for policy makers to increase productivity and adaptability to climate change.

References

[1] Abu, Orefi and Kirsten, Johann F.(2009) 'Profit efficiency of small- and medium-scale maize milling enterprises in South Africa', Development Southern Africa, 26: 3, 353-368.

[2] Admassie, Assefa and Heidhues, Franz (1996). 'Estimation of Technical Efficiency of Smallholder Farmers in the Central Highlands of Ethiopia", Ethiopian Journal of Agricultural Economics 1(1):19-35.

[3] Aigner, D.J., Lovell, C.A.K., Schmidt, P., 1977. Formulation and estimation of stochastic production function models. J. Econometrics 6, 21-37.

[4] Alem, Y., M. Bezabih, M. Kassie, P. Zikhali "Does fertilizer use respond to rainfall variability? Panel data evidence from Ethiopia" Agricultural Economics 41, 165-175, 2010.

[5] Basist, A., C., Williams, J., N. Grody, T.E.Ross, S.Shen, A.Chang, R.Ferraro, M.Menne.2001. Using the Special Sensor Microwave Imager to Monitor Surface Wetness. Journal of hydrometrology, 2, 297-308.

[6] Battese, G.E., Corra, G.S., 1977. Estimation of a production frontier model with application to the pastoral zone of Eastern Australia. Aust. J. Agric. Econ. 21, 169-179.

[7] Bedassa T., and S. Krishnamoorthy (1997). Technical efficiency in paddy farms of Tamil Nadu: an analysis based on farm size and ecological zone. Agricultural Economics 16 (1997) 185-192

[8] Belete, Abnet, J.L. Dillon, and F.M. Anderson (1993). "Efficiency of small-scale farmers in Ethiopia: a case study in the Baso and Warana sub-districts", Agricultural Economics 8:199-209.

[9] Dawson, P.J., Lingard, J., 1989. Measuring farm efficiency over time on Philippine rice farms. J. Agric. Econ. 40, 168-177.

[10] Deressa, T. 2010. Assessment of the vulnerability of Ethiopian agriculture to climate change and farmers' adaptation strategies. Unpublished PhD thesis. University of Pretoria , South Africa.

[11] Deressa, T., and R.M. Hassan. 2009. Economic Impact of Climate Change on Crop Production in Ethiopia: Evidence from Cross-Section Measures. *Journal of African Economies, 18, 529–554.*

[12] Deressa, T., R.M. Hassan, C. Ringler, A. Tekie and Mahmud Y. 2009. Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. *Global Environmental Change, 19, 248-255.*

[13] Donald, F. L. and FRANK P. (2002). Do farmers choose to be inefficient? Evidence from Bical, Phillipines. World Bank Policy Research Working paper 2787.

[14] FAO (Food and Agriculture Organization). 2003. The digital soil map of the world: Version 3.6 (January), Rome, Italy.

[15] Farrell, M. 1957, 'The measurement of productive efficiency', *Journal of the Royal Statistical Society*, vol 120, pp. 253-81.

[16] Hailu, G., Bitsch, V., Kassa, B. and Storck, H. (1998). "Technical Efficiencies of Smallholder annual Crop Production in Moisture Stress area of Eastern Oromiya of Ethiopia: A Stochastic Frontier Analysis", Ethiopian Journal of Agricultural Economics 2(2): 91-115.

[17] Hassan, R. & Nhemachena, C. 2008. Determinants of African farmers' strategies for adapting to climate change: multinomial choice analysis. *African Journal of Agricultural and Resource Economics*, 2(1):83–104.

[18] IWMI (International Water Management Institute) & University of Colorado .2003. hydro climatic data for the GEF/CEEPA/ World Bank Project on Regional Climate, Water and Agriculture: Impacts on and Adaptation of Agro-ecological Systems in Africa.

[19] IPCC (Intergovernmental Panel on Climate Change). 2001. Climate change: The scientific basis. [O]. Available:http://www.ipcc.ch/ Accessed 7 June 2008.

[20] Jondrow, J., Lovell, C.A.K., Materov, I.S., Schmidt, P., 1982. On estimation of the technical inefficiency in the stochastic frontier production function. J. Econometrics 19, 233-238.

[21] Kurukulasuriya, P. & Mendelsohn, R. 2008. Crop switching as a strategy for adapting to climate change. *African Journal of Agricultural and Resource Economics,* 2(1):105-125.

[22] Llewellyn R.V. and J. R. Williams .1996. Non- Parametric Analysis of Technical, Pure Technical and Scale Efficiencies for Food Crop Production in East Javal, Indonesia, Journal of Agricultural Economics. 15: 113-126

[23] Maddison, D. 2006. The perception of and adaptation to climate change in Africa.

[24] CEEPA. Discussion Paper No. 10. Centre for Environmental Economics and Policy in Africa. Pretoria: University of Pretoria.

[25] Mendelsohn, R., Nordhaus, W. & Shaw, D. 1994. The impact of global warming on agriculture: A Ricardian analysis. *American Economic Review* 84:753–771.

[26] Meeusen, W., Van den Broeck, J., 1977. Efficiency estimation from Cobb-Douglas production functions with composed error. Int. Econ. Rev., 34, 163-173.

[27] Mkhabela, T., Piesse, J., Thirtle, C. and Vink, N. (2010) 'Modelling efficiency with farm-produced inputs: dairying in KwaZulu-Natal, South Africa', Agrekon, 49: 1, 102-121.

[28] MoA (Ministry of Agriculture) .1998.Agro-ecological Zones of Ethiopia, Natural Resources Management and Regulatory Department, With Support of German Agency for Technical Cooperation (GTZ).

[29] Neff, D.L., Garcia, P., Nelson, C.H., 1993. Technical efficiency: a comparison of production frontier methods. J. Agric. Econ. 44, 479-489.

[30] Piesse, J., van Zyl, J., Thirtle, C. and Sartorius von Bach, H. 1996, 'Agricultural efficiency in South Africa's former homelands: measurement and implications' *Development Southern Africa*, vol 13, pp. 399-413.

[31] Schultz, T. W. (1964). Transforming Traditional Agricultural. Chicago: University of Chicago Press.

[32] World Bank. 2003. African Rainfall and temperature Evaluation System. Washington DC: World Bank.

Table 1: Districts surveyed in the sample agro-ecological zones

Number	*Agro-ecology*	**Districts**
1	Hot to warm sub-moist lowlands	Metema, Kefta Humera, Mi Tsebri, Tanqua Aberegele, Adama; Lume, Mieso, Dangur, Wembera, Sherkole
2	Tepid to cool sub-moist mid-highlands	Estie, Achefer, Bahirdar, Hawzen, Jijiga Zuria, Gursum
3	Tepid to cool pre-humid mid-highlands	Enarj Enawga, Gozemen, Sude, Chiro, Hagere Mariam, Dega, Kedida Gamela, Soddo Zuria, Beleso Sorie
4	Tepid to cool humid midlands	Ejere, Muka Turi
5	Hot to warm sub-humid lowlands	Galena Abeya, Oddo Shakiso, Pawe, Dibati, Bambesi, Assosa Zuria
6	Tepid to cool moist mid-highlands	Aleta Wendo, Chena, Robe, Sinana, Genesebo, Gera, Seka Chekorsa
7	Cold to very cold moist Afro-alpine	Adaba
8	Hot to warm humid lowlands	Konso, Sheko
9	Hot to warm arid lowland plains	Shinile, Gode, Gewane, Amibara, Dubti
10	Hot to warm per humid lowlands	Wenageo
11	Tepid to cool sub-moist mid-highlands	Bako

Table 2: Explanatory variables for the tobit model

Explanatory variables	Description
Winter temperature	Average temperature of December, January and February for the years 1988-2003 in degree centigrade
Summer temperature	Average temperature of June, July and August for the years 1988-2003 in degree centigrade
Spring temperature	Average temperature of March, April and May for the years 1988-2003 in degree centigrade
Fall temperature	Average temperature of September, October and November for the years 1988-2003 in degree centigrade
Winter precipitation	Average precipitation of December, January and February for the years 1977-2000 in millimeters
Summer precipitation	Average precipitation of June, July and August for the years 1977-2000 in millimeters
Spring precipitation	Average precipitation of March, April and May for the years 1977-2000 in millimeters
Fall precipitation	Average precipitation of September, October and November for the years 1977-2000 in millimeters
Education	Education of the head of household in years
Household size	The size of household in numbers
Nitosoles	Proportion of soil type nitosols in the district
Lithosols	Proportion of soil type lithosols in the district
Mean run-off	The mean run-off of the district in millimeters
Dummy 1	Takes the value of one if Hot to warm sub-moist lowlands and zero other wise
Dummy 2	Takes the value of one if Tepid to cool sub-moist mid-highlands and zero otherwise
Dummy 3	Takes the value of one of Tepid to cool pre-humid mid-highlands and zero otherwise
Dummy 4	Takes the value of one if Tepid to cool humid midlands and zero otherwise
Dummy 5	Takes the value of one if Hot to warm sub-humid lowlands and zero otherwise
Dummy 6	Takes the value of one if Tepid to cool moist mid-highlands and zero otherwise
Dummy 7	Takes the value of one if Cold to very cold moist Afro-alpine and zero otherwise
Dummy 8	Takes the value of one if Hot to warm humid lowlands and zero otherwise
Dummy 9	Takes the value of one if Hot to warm arid lowland plains and zero otherwise
Dummy 10	Takes the value of one if Hot to warm per humid lowlands and zero otherwise
Dummy 11	Takes the value of one if Tepid to cool sub-moist mid-highlands and zero otherwise

Table 3: OLS estimates of the Cobb-Douglas production function

Variables	Coefficients	P levels
Fertilizer	0.016	0.436
Labor	0.219***	0.000
Tractor	0.382***	0.000
draft power	0.032***	0.004
Farm size	0.029	0.478
Seed	0.009	0.589
Constant	5.661***	0.000
	N = 788	
	F = 44.72***	

*** represent significance at 1% level

Table 4: Maximum likelihood estimates of the Cobb-Douglas stochastic frontier model

Variables	Coefficients	P levels
Fertilizer	0.017	0.376
Labor	0.224***	0.000
Tractor	0.391***	0.000
Animal power	0.018*	0.100
Farm size	0.042	0.296
Seed	0.004	0.821
Constant	6.519***	0.000
	N = 788	
	$\sigma_u = 1.101$	
	$\sigma_v = 0.759$	
	$\sigma_u^2 + \sigma_v^2 = 1.787$	
	$\lambda = 1.451$	
	Likelihood-ratio test of sigma_u	
	Chaibar2(01) = 27.16***	

*, and *** represent significance at 10%, and 1% levels respectively

Table 5: Mean efficiency scores across the sample agro-ecological zones

Number	*Agro-ecology*	**Average efficiency scores**
1	Hot to warm sub-moist lowlands	0.53
2	Tepid to cool sub-moist mid-highlands	0.61
3	Tepid to cool pre-humid mid-highlands	0.41
4	Tepid to cool humid midlands	0.47
5	Hot to warm sub-humid lowlands	0.43
6	Tepid to cool moist mid-highlands	0.54
7	Cold to very cold moist Afro-alpine	0.57
8	Hot to warm humid lowlands	0.51
9	Hot to warm arid lowland plains	0.50
10	Hot to warm per humid lowlands	0.44
11	Tepid to cool sub-moist-highlands	0.48
	Total sample farmers	**0.50**

Table 6: Parameter estimates of the tobit model

Variables	Coefficients	P values
Education	0.001	0.546
Household size	-0.001	0.758
Nitosoles	0.120***	0.001
Lithosoles	0.376*	0.036
Mean run-off	0.004***	0.000
Log[1] Winter Temperature	0.507	0.432
Log Spring temperature	-1.793***	0.000
Log Summer temperature	-3.604***	0.000
Log Fall temperature	5.170***	0.000
Log Winter Precipitation	-0.377***	0.002
Log Spring precipitation	0.905***	0.001
Log Summer precipitation	0.379***	0.000
Log Fall precipitation	-1.151***	0.000
Dummy1	0.216*	0.015
Dummy2	0.184***	0.006
Dummy3	-0.061	0.275
Dummy4	0.043	0.377
Dummy5	0.037	0.509
Dummy6	0.162***	0.000
Dummy7	0.093***	0.007
Dummy8	0.091*	0.026
Dummy9	0.050	0.144
Dummy10	-0.114***	0.002
Constant	0.237	0.428

*, and *** represent significance at 10% and 1% levels respectively

[1] Natural logarithm